General Application Name: Public Works/Service Authority

Product / Service / Function Name: Pipe Inventory

P/S/F Description:

A pipe inventory involves locating, documenting, and managing all pipes (functional and abandoned) within a sanitary sewer system and/or water distribution system. A water pipe inventory commonly includes water mains, lateral water mains, service pipes and associated attributes (i.e., diameter, material type). Wastewater pipe inventory consists of a series of gravity flow mains and force mains of varying diameters, and related attributes.

A relatively new mandate called the Governmental Accounting Standards Board Statements Number 34: Basic Financial Statements – and Management Discussion and Analysis – for State and Local Government (GASB 34), will make government asset inventories, including pipe inventories, directly useful for government accounting. GASB 34 redefines the accounting standards for state and local governments. Organizations must either calculate the historic cost of each asset minus its depreciation through time, or develop an infrastructure asset inventory and management system that will generate an accurate inventory of all assets, report the condition of assets every three years, and determine the annual estimate of the cost needed to maintain the asset in its current conditions. Because of its unique ability to relate individual components and their attributes to specific locations, GIS is well suited for creating and maintaining detailed, auditable infrastructure inventories.

Product / Service / Function

1. Spatial Data -

   Minimum Data Requirements

General Description	Data Layer
Sewer Utilities	Gravity mains
	Force mains
Water Utilities	Water mains
	Hydrant laterals
	Service laterals
Planimetrics/Base Mapping	Parcel boundaries
Transportation	Right-of-way and/or edge of pavement
Socio-Political Data	Political boundaries

   Optional Data Requirements

General Description	Data Layer
Sewer Utilities	Pump Station
	Sub-basin
	Service Area
	Treatment Plant
	Manhole ID

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	Valve
	Flow Meter
	Inlets
Water Utilities	Hydrant
	Pump Station
	Tank
	Well
	Treatment Plant
	Meter
	Valve (air, blow-off, hydrant)
	Reducer
Natural Features	Watersheds
	Streams/rivers
	Slope
	Ponds/lakes
Planimetrics/Base Mapping	Building footprints
Raster	Orthophotography
	Video logs

2. Attribute Data -

Minimum Attribute Requirements

General Description	Field Name
Sewer Pipe	Unique ID
	From-node ID
	To-node-ID
	Length
	System ID
	Construction date
	Material type
	Pipe diameter
	Type of flow (gravity, pressure)
	Inspection date
	Condition
Water Pipe	Unique ID
	From-node ID
	To-node-ID
	Length
	Construction date
	System ID
	Material type
	Pipe diameter
	Inspection date
	Condition
Right-of-ways	Street names

Optional Attribute Requirements

General Description	Field Name
Sewer Pipe	Latest renovation date
	Pipe Utilization (outfall, collection)
	Maintenance data
	Slope
	Roughness
	Minor Loss
	Pressure Rating
	Lining Type
	Joint Type
Water Pipe	Latest renovation date
	Maintenance
	Slope
	Pressure Rating
	Lining Type
	Joint Type
	Slope
Hydrants	Hydrant ID
	Pressure
Valves	Valve type
	Diameter
Manholes	Manhole ID
	Elevation
	Invert In/Invert Out
	Diameter

3. Data Acquisition Options (integrated with VBMP digital orthos)

Sewer and water pipe geometry and attributes can be captured either through field collection with Global Positioning Systems (GPS), or digitization and data entry from as-built drawings, maps, service cards, hydrant cards, and other drawings. The data collection method chosen will depend on the desired level of accuracy, availability, quality, time frame, and budget. When collecting pipe information, it is important to consider the direction of flow through the system to minimize data "clean-up" for future modeling efforts.

Because pipes are located below the surface, the lines cannot be directly captured through GPS. Often local government agencies or consulting firms will capture accurate manhole locations (points) in the field. If possible manhole locations should be recorded according to the direction of flow. The point data is then processed. Using GIS software, the points are connected with lines to generate the pipe spatial layer. Attributes are then manually entered into the database from hardcopy information, or existing databases are linked to a common attribute field.

Alternatively, hardcopy as-built drawings, maps, plats, cards, and other documents can be scanned, registered to the coordinate system, and digitized. Lines should be digitized following the direction of flow. Annotation on paper can be added to the feature's database during the digitization process. Some as-built drawings may already be in digital format, maintained as Computer-aided Drafting (CAD) files. With some processing and manipulation, these files can be converted into seamless GIS data layers.

Parcels and building footprint data are typically maintained at the county level. Other spatial data layers (i.e., political boundaries, streams/rivers, watersheds) can be obtained through the Internet or directly from various external sources. Before using data from external organizations it is important to assess data scale, accuracy, precision and geographic coverage.

Additionally, current systems and databases within the organization may be linked to a pipe inventory system, such as an accounting system, water quality database, or pipe monitoring network. Data from these sources could be migrated and integrated with the pipe inventory system.

Regardless of the source of the data, each data layer used for the pipe inventory should be consistent with, or be modified to match, the Virginia Base Mapping Project orthophotography. This is vital for data consistency across the state and facilitates data sharing across jurisdictional boundaries. The digital orthophotography provides an excellent base data layer on which to display sewer and water pipe data and also visually verify the data.

4. Data Conflation Options (integrated with VBMP digital orthos)

Data conflation is a process by which two digital data layers, usually of the same area at different points in time, or two different data layers of the same area, are geographically "corrected" through geometrical and rotational transformations so that the different layers can be overlaid on one another. Also called "rubber-sheeting," this process allows a technician to adjust the coordinates of all features on a data layer to provide a more accurate match between known locations and a few data points within the base data set. A good base layer to use for data conflation is the VBMP orthophotos since many features can be seen or interpreted. The need and processes for conflation varies between sets of data, users, and feature types. Any dataset that is updated independently by different departments can be consolidated through conflation. Within most local governments, individual departments are responsible for maintaining specific datasets within their expertise; therefore, conflation is not often necessary. Often, reprojecting the data into a different coordinate system will take care of the misalignment of different data sets. Most industry-standard GIS software has the ability to perform data conflation.

It is important to either capture the pipe geometry in the same projection as the VBMP orthophotography or reproject it later to match the orthophotos. This ensures that when the data are converted into a GIS data layer, the pipes will appear in the correct location on top of the orthophotos. Accurate location of pipe lines is critical because of easement and right-of-way issues.

5. GUI / Programming Options:

A comprehensive pipe inventory system may include tools to record maintenance efforts, responses to customer needs, anticipated expenses, and reporting assets in compliance with GASB 34, along with general inventory management. Local government organizations have several options for accessing and visualizing the inventory data.

There are many options for developers of a GIS-based water and/or sewer pipe inventory systems. Three possibilities for application development are:

- A standard GIS desktop application that can be customized to the user's needs
- Existing commercial sewer and water pipe inventory system
- Hiring a consultant to develop a custom system from scratch.

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Using standard GIS software often requires a significant amount of training and customization. Whereas the initial cost may be lower, the time invested in learning these solutions may generally increase the overall expense of implementation. However, standard GIS software packages deliver more robust data integration, analysis, and cartographic capabilities than do other specialized commercial applications. They have a greater user support infrastructure that allows users to overcome problems quickly. Options for using an existing, industry-standard GIS software application that can be customized for a pipe inventory system include those listed in the following table:

Standard GIS Software Vendors:

Vendor	**Software**	**Web Address**
ESRI	ArcView 3.x	http://www.esri.com
ESRI	ArcGIS 8.x	http://www.esri.com
MapInfo	Professional 7.0	http://www.mapinfo.com
Intergraph	GeoMedia 5.0	http://www.intergraph.com/gis
Autodesk	Map 5.0	http://www.autodesk.com

With the arrival of GASB 34, there has been an increasing number of vendors developing and implementing pipe inventory software. These products may often cost more than off-the-shelf solutions because of the customization that is required to fit the application into the agency's business practices and/or connect to existing databases. The advantage is that a tailored application provides just the functionality that is needed, decreasing the overall application overhead common to industry-standard GIS software. Options for using an existing, commercial pipe inventory system include those listed in the following table:

Vendor	**Software**	**Web Address**
RPT, Inc.	GeoPlan	http://www.rpt.com
Azteca Systems	CityWorks	http://www.azteca.com
CarteGraph	WATERview	http://www.cartegraph.com
Hansen	Hansen 7.5	http://www.hansen.com

The final option for developing and implementing a pipe inventory system is to contract a consultant. This option makes certain that a product will fulfill an agency's requirements. Unlike the first option, which requires the organization to modify its own process/technology to fit the system, the system fits existing business practices. A consultant will be able to develop an application that works with the wide range of systems that currently exist. Also, training and follow-up user support is often provided at a much more substantial level than with other options.

A pipe inventory application could provide several different functionalities. For example, the application could allow the user to create a maintenance log, track work orders, manage labor or equipment, or maintain an inspection and testing history.

6. Internet Functionality and Options:

The Internet has proven itself as a viable solution for local governments to centralize the maintenance and management of services and data. As more local governments are implementing Web-based solutions, they are finding that the Internet requires them to change the nature of an application or its usefulness. Through the flexibility of an Internet solution, software

can be easily updated, and users gain greater accessibility to the applications and information they need for their specific tasks through simple, user-friendly interfaces.

If a local government so chooses, they can deploy a Web GIS application to allow citizens of their community to view maps of the water/sewer pipe systems created from the pipe inventory. GIS software vendors have products that can be customized in-house or by a consultant to provide Web GIS applications on the Internet, over an intranet or via wireless network.

GIS Internet Solutions

Vendor	Internet Software	Web Address
ESRI	ArcIMS	http://www.esri.com/software/arcims
MapInfo	MapXtreme, MapX	http://www.mapinfo.com
Intergraph	GeoMedia WebMap	http://www.intergraph.com/gis/gmwm
Autodesk	MapGuide	http://www.autodesk.com

7. Technical Requirements:

Minimum Technical Requirements
At its most basic level, a sewer and/or water pipe inventory system can be used on a single, stand-alone workstation. This workstation would have a hard drive that stores all of the spatial data layers, as well as a database containing a copy of all of the incident records for the law enforcement agency. A typical workstation running off-the-shelf software should have the following minimum specifications:

Processor: Pentium 3, 450 MHz
RAM: 128MB SDRAM at 133MHz
Hard Disk: 20GB (min.)
Monitor 1: 19"
Floppy Drive: 3.5”
CD-ROM: 12x/8x/32x CD drive
Modem: 56K
OS: Windows 2000/NT/XP
Office: Windows 2000 Professional
Printer: 8x11 office-grade color printer

Optimum Technical Requirements:
A more complex pipe inventory system may require multiple components, including servers, desktop workstations, ruggedized laptops, and/or handheld devices. For either a client-server or a Web-based application, the system should rely on a fairly robust server computer and high-end workstations. Some examples specifications of the necessary equipment are listed below:

Server
Processor: Min. 2x Processors, 1.7 GHz, 512K cache
RAM: Min. 2x 512MB RIMMS
Hard Disk: Min. 2x 80GB +RAID
Monitor 1: 19"
Floppy Drive: 3.5”
CD-ROM: 12x/8x/32x CD drive

Modem: 56K
Network Card: 10/100 mbps

Workstation
Processor: Pentium 4, 1.5 GHz
RAM: 512MB SDRAM at 133MHz
HardDisk: 20GB (min.)
Monitor 1: 19”
Monitor 2: 17”
Floppy Drive: 3.5”
CD-ROM: 12x/8x/32x CD-RW drive
Modem: 56K
Network Card: 10/100 mbps
OS: Windows 2000/NT/XP
Office: Windows 2000 Professional

Other Components
Printer: 8x11 office-grade color printer and 8x11 production b/w printer
Plotter: HP DesignJet 1055CM
Tape Backup: Tape Library Server
UPS: APC 1400 (or other similar)
Scanner: 11x17
Handheld: Compaq IPAQ
Network: T1
GPS Equipment: Receiver, Antenna, Data Processing software (various vendors)

8. Administrative/Management Requirements

At the beginning of the project the assigned project manager should consider completing some, if not all of the following tasks that relate to the administrative requirements of a pipe inventory project:

- Determine, with or without the assistance of a consultant hired to develop the system, the preliminary vision and goals of the project.
- Coordinate an initial stakeholders meeting where the vision and goals of the project are expressed and the background of GIS technology is described, if needed.
- Coordinate with other government agencies for data sharing provisions.
- Determine a mechanism of communication to keep the stakeholders (e.g. Board of Supervisors, City Council, public works department, engineering department, etc.) aware of the progress of the project.
- Develop a basic understanding of the available precedents in their region/state and research the available technologies that can be applied to their project.

Upon project completion, a simple desktop pipe inventory application will require very little administrative support. Administrative tasks may include loading or upgrading new versions of the software or patches, providing for constant data flow from the other systems, and maintaining yearly support contracts on the hardware and software. However, once the system becomes widely distributed, there are various other management requirements that need to be fulfilled on a weekly or monthly basis.

At the point where the system grows beyond single desktop users, a devoted administrator or system manager needs to be established. This is essential for the following reasons:

- The system will now be interfacing with other technology systems already in place, and, therefore, someone needs to maintain contact with the technology personnel that maintain these systems.
- The manager needs to put into place quarterly training schedules to maintain user knowledge of the system.
- Funding will undoubtedly be required to either maintain the system long-term, or continue to expand the system, which requires funding research and applications for grants.
- Pipe inventory systems only succeed when it is implemented on a weekly basis with rigorous analysis and planning.

9. Cost – Cost/Benefit:

Hardware	**Typical Unit Cost**
Minimum Workstation	$2,000
Optimum Workstation	$3,200
Laptop	$2,400
Web/FTP Server	$8,500
Database Server	$12,000
Data Warehouse Server	$18,000
Backup Server	$5,800
Printer (8x11 color)	$700
Printer (8x11 b/w production)	$2,000
Plotter	$12,000
Tape Library	$5,000
UPS	$700
Scanner	$1,500
Handheld	$300-$700
GPS Equipment	$5,000 - $15,000

Software (all prices included license)	**Typical Unit Cost**
Standard GIS desktop software	$700-$10,000
Vendor pipe inventory application	$6,000-$20,000
Customized vendor solution	$20,000-$50,000
Web-based vendor application	$15,000-$35,000
Customized web-based vendor solution	$20,000-$60,000

Miscellaneous	**Typical Unit Cost**
Training – focused vendor pipe inventory (per person)	$1,00-$5,000
Training – general GIS	$700-$1,200
Licensing-desktop	$300-$1,500
Licensing-webapp (1st CPU)	$7,500-$12,000
Maintenance (per year)	$8,000-$15,000
GPS survey by a consultant	$15,000-$90,000 (depends on

	number of features)

10. Standards / Guidelines Summary

- Review options for creating the pipe data. This should be followed by documenting the technical specifications for the spatial features, and database design.
- If purchasing GPS equipment, consider the organization's needs for accuracy, mobility, cost, equipment durability, and differential correction methodologies.
- Consider collecting too many attributes rather than not enough. It may be too expensive to go back later and re-survey to obtain attributes that were left out in the first pass.
- If digitizing off of scanned drawings/maps, be sure to use a minimum of four reference points when registering the images. Also, the resulting vector files should be cleaned to ensure that all features are properly snapped together, and there are no overshoots or undershoots.
- Pipe location information should be digitized or collected through GPS with consideration to the direction of flow whenever possible.
- Do a "pilot area" first to review initial data collected to see if a revised plan is needed before moving on to the rest of the inventory.
- Standardize procedures for adding new features to the spatial layers.
- Develop a detailed Quality Assurance/Quality Control (QA/QC) procedure for reviewing the accuracy of the GIS data and its attributes.
- Maintain data in the VBMP standard coordinate system (Virginia State Plane, NAD 83, Survey Feet).
- Create metadata (standard information about GIS data) for each data layer. Metadata tracks the date, origin, coordinate system, and other such information for data layers.

11. Startup Procedures/Steps

A pipe inventory is a very large project; therefore, careful planning will make the process go more smoothly. There are at least eight steps involved with doing the pipe inventory and developing a GIS-based pipe inventory system. The steps can be performed in-house or by a consulting team.

The first task is to complete a detailed Needs Assessment. This process gathers information regarding existing operational procedures, hardware and software, GIS data, and personnel needs. It should include interviews of key individuals throughout the local government agency and other related government departments to obtain a comprehensive view of the agency's operations, and where GIS might improve them. Basic GIS concepts should be discussed and illustrated to those interviewees that have little prior understanding of GIS. A comprehensive Needs Assessment should then be compiled from the results of the interviews. This document explains the various requirements for a pipe inventory system in the following areas: personnel needs, spatial data development needs, applicable spatial analysis techniques, basic system requirements, including preliminary, general hardware and software recommendations, and training needs.

The second task is to develop a functional requirements document for the proposed system. This document should describe, as completely as possible, all of the technology and functionality that is to be included in the pipe inventory system:

- Hardware specifications
- Software purchases
- Detailed descriptions of work-flow, and examples of the graphic user interfaces
- Describe each tool that is part of that graphic user interface, and its functionality

- Describe how data would flow between the different databases and data warehouses, if applicable
- Describe the redundant security measures that will be put in place to make certain of data integrity and confidentiality, when applicable
- Analytical techniques that the application/system provides
- Describe each of the potential products (reports, maps, charts, summary tables) that the user will be able to generate within the system

The third task should be to compile or develop a spatial data set that can be used by the evolving pipe inventory system. Data can be gathered from a number of online sources, as well as county/city departments. The data layers gathered and maintained should match at least the minimum list provided in Section 1 of this document.

On completion and acceptance of the functional requirements document and the development of the spatial and attribute data, the system development and test phase can begin. During this time, the application will be customized as it was outlined in the functional requirements phase. The local government agency should require periodic reviews of the application at particular milestones, such as 50% and 75% completion. This will make certain that problems with the application will be recognized early in the development process, and that the local government agency remains a part of the development process throughout the project timeline.

When the application is nearing 100% completion, it should be installed and tested in the environment in which it will ultimately be used. This allows the users to test the system alongside the application developers, and determine any system integration problems that might arise. It also gives the developers the opportunity to test the application's functionality in a real-world situation. This testing process should be as comprehensive as possible. Each process detailed within the functional requirements should be tested and evaluated at this point.

User training commences once the application reaches 100% completion and is fully documented. Different levels of tutorials and system documentation should be developed depending on the hierarchy of users. Time should be spent at this stage of the project with each potential user of the system to make certain that the proper education occurs. Training should be done through lessons that use real-life examples of system application. This strategy greatly enhances users' ability to apply the functionality to their jobs.

The final phase of a successful pipe inventory system is ongoing technical support. The local government agency should always include this contingency within its cost estimates of a project for a minimum of three months after a system has been put into place. No matter how effective an application appears, problems and system changes inevitably impact the functionality.

12. Estimated time line and/or implementation (stand alone) schedule:

Phase	**Duration**
RFP/Contract process (construction, posting, proposal acceptance, review, award of contract)	4 months - 1 year
Needs Assessment	2-3 months
Functional Requirements	2-3 months
Data Development	6 months – 12 months
System Development and Testing	2-4 months

Installation and Testing	1 month
User Training	½ month
Plan for Future Development	1 month
Ongoing Support	3 months

13. Best Practice Examples in Virginia

Spotsylvania County
Department of Utilities
600 Hudgins Road
Spotsylvania, VA 22408
(504) 898-2053
http://www.co.spotsylvania.va.us

Henrico County
4301 E. Parham Rd
Richmond, VA 23228
(804) 501-5769
http://www.co.henrico.va.us

Augusta County Service Authority
18 Government Center Lane
Verona, VA 24482
540-245-5670
http://www.acsawater.com

City of Newport News
GIS - Waterworks
700 Town Center Drive
Newport News, VA 23607
(757) 247-2640
http://www.nngov.com